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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]This invention relates to nonaqueous electrolyte excellent in the charging and discharging characteristic, and the rechargeable battery using it. It is related with nonaqueous electrolyte suitable for the lithium secondary battery containing the compound which contains a cyanoethyl group in details more, and the rechargeable battery using it.

[0002]

[Background of the Invention]The cell using nonaqueous electrolyte is high tension, and has high energy density.

Since reliability, such as keeping, is high, it is widely used as a power supply of consumer electronics.

[0003]There is a nonaqueous electrolyte secondary battery as such a cell, and the typical existence is a rechargeable lithium-ion battery. As a nonaqueous solvent used for it, the carbonate compound with a high dielectric constant is known, and use of various carbonate compounds is proposed. As an electrolysis solution, said high permittivity carbonate compound solvents, such as propylene carbonate and ethylene carbonate, The solution which mixed electrolytes, such as LiBF_4 , LiPF_6 , LiClO_4 , LiAsF_6 , LiCF_3SO_3 , and Li_2SiF_6 , is used for the mixed solvent with low viscosity solvents, such as diethyl carbonate.

[0004]On the other hand, research of the electrode is also advanced aiming at high-capacity-izing of a cell, and the occlusion of lithium and the carbon material which can be emitted are used as a negative electrode of a rechargeable lithium-ion battery. Since it has the features, like discharge potential is flat and there is, especially high crystallinity carbon, such as black lead, is adopted as a negative electrode of most rechargeable lithium-ion batteries marketed now.

[0005]However, when using high crystallinity carbon, such as black lead, for a negative electrode, as a nonaqueous solvent for electrolysis solutions, When the propylene carbonate which is a low high dielectric constant solvent of a coagulating point, and 1 and 2 **BUCHIREN carbonate are used, the reductive cleavage of a solvent occurs at the time of charge, and the insertion reaction to black lead of the lithium ion which is an active material will hardly advance, and stops achieving the function of an electrolysis solution. As a result, especially, first-time charge and discharge efficiency falls extremely.

[0006]For this reason, as a nonaqueous solvent of the high permittivity used for an electrolysis solution,

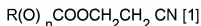
although it is a solid at ordinary temperature, when reductive cleavage mixes the ethylene carbonate which does not happen easily continuously to propylene carbonate, the trial which suppresses the reductive cleavage of a nonaqueous solvent is made. In order to improve the viscosity characteristic of a nonaqueous solvent furthermore in addition to control of reductive cleavage, devising how with a low viscosity solvent to combine, adding various additive agents, or restricting the content of the propylene carbonate in an electrolysis solution etc. is proposed. Although improvement in the charging and discharging characteristic of a cell and the low-temperature characteristic has been achieved by these measures, the more highly efficient electrolysis solution is called for now.

[0007]

[Problem(s) to be Solved by the Invention]In order for this invention to respond to the aforementioned request, even if it is a case where high crystallinity carbon, such as black lead, is used for a negative electrode, the reductive cleavage of a solvent is inhibited and it aims at offer of the nonaqueous electrolyte which gives charge and discharge efficiency, a load characteristic, and the low-temperature characteristic excellent in the cell. It aims at offer of the rechargeable battery containing this nonaqueous electrolyte.

[0008]

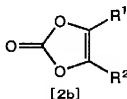
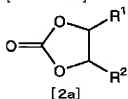
[Means for Solving the Problem]Nonaqueous electrolyte concerning this invention is related with nonaqueous electrolyte which consists of a nonaqueous solvent containing a compound containing a cyanoethyl group expressed with a general formula [1], and an electrolyte.



(R is hydrogen, a hydrocarbon group of the carbon numbers 1-10, or $-\text{CH}_2\text{CH}_2\text{CN}$ among a formula [1], and n is 0 or 1)

[0009]If the aforementioned nonaqueous solvent comprises a compound containing a cyanoethyl group expressed with said general formula [1], and cyclic carbonate expressed with a following general formula [2a] or [2b] and/or chain carbonic ester, further outstanding nonaqueous electrolyte can be provided.

[Formula 2]



(R1 and R2 show an alkyl group of a hydrogen atom or the carbon numbers 1-6 among a formula [2a] or [2b], and R1 and R2 may be the same, or they may differ.)

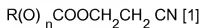
[0010]These nonaqueous electrolyte can be effectively used as an electrolysis solution for a primary battery or rechargeable batteries as it is the nonaqueous electrolyte which lithium salt as an electrolyte dissolved.

[0011]This invention A negative electrode which includes metal lithium, a lithium content alloy, or a carbon material in which a dope and a dedope of a lithium ion are possible as negative electrode active material, It is related with a rechargeable battery containing an anode which contains either a multiple oxide of lithium and a transition metal, carbon materials or these mixtures as positive active material, and said nonaqueous electrolyte.

[0012]

[Detailed Description of the Invention]Next, the nonaqueous electrolyte concerning this invention and the nonaqueous electrolyte secondary battery using this nonaqueous electrolyte are explained concretely. The nonaqueous electrolyte concerning this invention consists of a nonaqueous solvent containing the compound containing a cyanoethyl group, and an electrolyte, and explains each in full detail.

[0013]The compound expressed with a following general formula [1] as a compound containing the cyanoethyl group which a nonaqueous solvent is made to contain by compound this invention containing a cyanoethyl group is used. In this invention, a cyanoethyl group shows $\text{-CH}_2\text{CH}_2\text{CN}$.



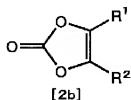
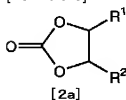
[0014]In said formula [1], R is hydrogen, a hydrocarbon group of the carbon numbers 1-10, or $\text{-CH}_2\text{CH}_2\text{CN}$, and n is 0 or 1. As R, specifically Hydrogen, a methyl group, an ethyl group, a vinyl group, a propyl group, An isopropyl group, 1-propenyl group, 2-propenyl group, an methacrylic group, 1-propynyl group, 2-propynyl group, a butyl group, an isobutyl group, a sec-butyl group, t-butyl group, 1-butenyl group, 2-butenyl group, 3-butenyl group, A 2-methyl-2-propenyl group, 1-methylenepropyl group, a 1-methyl-2-propenyl group, A 1,2-dimethylvinyl group, 1-butylnyl group, 2-butylnyl group, 3-butylnyl group, A pentyl group, 1-methylbutyl group, 2-methylbutyl group, 3-methylbutyl group, The straight chain, branched alkyl group, or cyanoethyl groups of the carbon numbers 1-10, such as a 1-methyl-2-methylpropyl group, a 2,2-dimethylpropyl group, other hexyl groups, an octyl group, a nonyl group, and a decyl group, can be mentioned.

[0015]Specifically in the compound expressed with said general formula [1], 2-cyanoethyl propionate, methyl-2-cyanoethyl carbonate, etc. are especially mentioned as a desirable compound. The reductive cleavage of the nonaqueous solvent at the time of charge is inhibited to the compound containing the cyanoethyl group expressed with said such general formula [1], and there is an effect of improving charge and discharge efficiency in it.

[0016]un--- In the nonaqueous electrolyte concerning aqueous solvent this invention, the nonaqueous solvent containing the compound containing the cyanoethyl group expressed with said general formula [1] is used. The compound containing this cyanoethyl group can be used as the additive agent to the nonaqueous solvent generally used, or one solvent which constitutes a nonaqueous solvent. The compound containing a cyanoethyl group to the whole (total quantity of the compound and nonaqueous solvent containing a cyanoethyl group) nonaqueous solvent 0.001 % of the weight or more, It is preferably desirable to be especially contained in 0.05 to 30% of the weight of quantity preferably 0.01 to 70% of the weight still more preferably 0.01 to 99.5% of the weight. It is preferred to use the nonaqueous solvent which contains the cyclic carbonate expressed with the compound, the following general formula [2a], or [2b] containing the above-mentioned cyanoethyl group and/or chain carbonic ester especially in the nonaqueous electrolyte concerning this invention.

[0017]The cyclic carbonate expressed with the general formula [2a] or [2b] shown below as a nonaqueous solvent which can be used, and/or chain carbonic ester can be mentioned.

[Formula 3]



Here, in a formula [2a] or [2b], R1 and R2 show an alkyl group of a hydrogen atom or the carbon numbers 1-6, and R1 and R2 may be the same, or they may differ. In this, as an alkyl group, an alkyl group of the carbon numbers 1-3 is preferred, and a methyl group, an ethyl group, and n-propyl group can specifically be illustrated.

[0018]As an example of cyclic carbonate expressed with such a formula [2a] or [2b], specifically, Ethylene carbonate, propylene carbonate, 1, 2 **BUCHIREN carbonate, 2, 3 **BUCHIREN carbonate, 1, 2 **PENCHIREN carbonate, 2, 3 **PENCHIREN carbonate, vinylene carbonate, etc. are mentioned. In particular, a dielectric constant is high and viscosity and low propylene carbonate of a coagulating point are used suitably. Two or more sorts may use these cyclic carbonate, mixing.

[0019]Specifically, dimethyl carbonate, methylethyl carbonate, diethyl carbonate, methylpropyl carbonate, methylisopropyl carbonate, ethylpropyl carbonate, etc. are mentioned as chain carbonic ester. Two or more sorts may use these chain carbonic ester, mixing.

[0020]If such chain carbonic ester is contained in a nonaqueous solvent, it will become possible to make viscosity of nonaqueous electrolyte low, electrolytic solubility will be raised further, and it will be considered as an electrolysis solution excellent in electrical conductivity in ordinary temperature or low temperature -- things can be carried out. For this reason, the low-temperature characteristic like charge and discharge efficiency of a cell and charge and discharge efficiency [in / for example, / low temperature], and a load characteristic in low temperature is improvable.

[0021]When using cyclic carbonate expressed with said general formula [2a] or [2b], and/or chain carbonic ester as a nonaqueous solvent, A compound containing a cyanoethyl group expressed with said general formula [1], The nonaqueous solvent whole containing it (with a compound containing a cyanoethyl group expressed with said general formula [1].) To the total quantity with cyclic carbonate expressed with said general formula [2a] or [2b], and/or chain carbonic ester, 0.001 % of the weight or more, It is preferably desirable to be most preferably contained in 0.05 to 30% of the weight of quantity 0.01 to 70% of the weight still more preferably 0.01 to 99.5% of the weight.

[0022]If a compound containing a cyanoethyl group expressed with such the mixing ratio by said general formula [1] is contained in the whole nonaqueous solvent containing it, reductive cleavage of a solvent which happens at the time of charge can be suppressed low, and improvement in charge and discharge efficiency of a cell and an improvement of the low-temperature characteristic can be aimed at. The mixing ratio of cyclic carbonate expressed with said general formula [2a] or [2b] in a nonaqueous solvent, and chain carbonic ester, expressing with a weight ratio -- cyclic carbonate:chain carbonic ester -- 0:100-100:0 -- desirable -- 5:95-95:5 -- it is 20:80-85:15 especially preferably.

[0023]Therefore, a desirable nonaqueous solvent concerning this invention contains a compound containing cyanoethyl expressed with said general formula [1], cyclic carbonate expressed with said general formula [2a] or [2b], and/or said chain carbonic ester. It is also possible to carry out mixed use of the solvent usually widely used as a nonaqueous solvent for cells further in addition to them. That it is concrete as an example of a solvent, methyl formate, ethyl formate which can be used, Propyl formate, methyl acetate, ethyl acetate, propyl acetate, methyl propionate, chain ester, such as ethyl propionate; . phosphoric ester, such as trimethyl phosphate; . chain ether, such as dimethoxyethane; Cyclic ether, such as a tetrahydrofuran; Amide, such as dimethylformamide; Chain Cava mates, such as the methyl N and N **JIMECHIRUKABA mate; Cyclic ester,

such as gamma-butyrolactone; . Annular sulfones, such as sulfolane; Annular Cava mates, such as N **MECHIRU oxazolidinone; cyclic amide, such as N **MECHIRU pyrrolidone; Annular urea, such as N,N **JIME chill imidazolidinone; 4,4-dimethyl- 5-methylene ethylene carbonate, 4-methyl-4-ethyl-5-methylene ethylene carbonate, 4-methyl-4-propyl-5-methylene ethylene carbonate, 4-methyl-4-butyl-5-methylene ethylene carbonate, 4,4-diethyl- 5-methylene ethylene carbonate, 4-ethyl-4-propyl-5-methylene ethylene carbonate, 4-ethyl-4-butyl-5-methylene ethylene carbonate, 4,4-dipropyl- 5-methylene ethylene carbonate, 4-propyl-4-butyl-5-methylene ethylene carbonate, 4,4-dibutyl- 5-methylene ethylene carbonate, 4,4-dimethyl- 5-ethylidene ethylene carbonate, 4-methyl-4-ethyl-5-ethylidene ethylene carbonate, 4-methyl-4-propyl-5-ethylidene ethylene carbonate, 4-methyl-4-butyl-5-ethylidene ethylene carbonate, 4,4-diethyl- 5-ethylidene ethylene carbonate, 4-ethyl-4-propyl-5-ethylidene ethylene carbonate, 4-ethyl-4-butyl-5-ethylidene ethylene carbonate, 4,4-dipropyl- 5-ethylidene ethylene carbonate, 4-propyl-4-butyl-5-ethylidene ethylene carbonate, 4,4-dibutyl- 5-ethylidene ethylene carbonate, 4-methyl-4-vinyl-5-methylene ethylene carbonate, 4-methyl-4-allyl-5-methylene ethylene carbonate, 4-methyl-4-methoxymethyl 5-methylene ethylene carbonate, 4-methyl-4-acrylic oxymethyl 5-methylene ethylene carbonate, Cyclic carbonate, such as 4-methyl-4-aryloxymethyl 5-methylene ethylene carbonate; 4-vinyl ethylene carbonate, Vinyl ethylene carbonate derivatives, such as 4,4-divinyl ethylene carbonate and 4,5-divinyl ethylene carbonate; 4-vinyl-4-methyl ethylene carbonate, 4-vinyl-5-methyl ethylene carbonate, 4-vinyl-4,5-dimethyl ethylene carbonate, Alkylation vinyl ethylene carbonate derivatives, such as 4-vinyl-5,5-dimethyl ethylene carbonate and 4-vinyl-4,5,5-trimethylethylene carbonate; 4-aryloxymethyl ethylene carbonate, Aryloxymethyl ethylene carbonate derivatives, such as 4,5-diaryl oxymethyl ethylene carbonate; 4-methyl-4-aryloxymethyl ethylene carbonate, Alkylation aryloxymethyl ethylene carbonate derivatives, such as 4-methyl-5-aryloxymethyl ethylene carbonate; 4-acrylic oxymethyl ethylene carbonate, Acrylic oxymethyl ethylene carbonate derivatives, such as 4,5-acrylic oxymethyl ethylene carbonate; 4-methyl-4-acrylic oxymethyl ethylene carbonate, Alkylation acrylic oxymethyl ethylene carbonate derivatives, such as 4-methyl-5-acrylic oxymethyl ethylene carbonate; A compound etc. which are expressed with a following general formula are mentioned. $\text{HO}(\text{CH}_2\text{CH}_2\text{O})_a\text{H}$, $\text{HO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_b\text{H}$, $\text{CH}_3\text{O}(\text{CH}_2\text{CH}_2\text{O})_c\text{H}$, $\text{CH}_3\text{O}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_d\text{H}$, $\text{CH}_3\text{O}(\text{CH}_2\text{CH}_2\text{O})_e\text{CH}_3$, $\text{CH}_3\text{O}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_f\text{CH}_3$, $\text{C}_9\text{H}_{19}\text{PhO}(\text{CH}_2\text{CH}_2\text{O})_g(\text{CH}(\text{CH}_3)\text{O})_h\text{CH}_3$ (Ph is a phenyl group), $\text{CH}_3\text{O}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_i\text{CO}(\text{O}(\text{CH}_3)\text{CHCH}_2)_j\text{OCH}_3$ (among the aforementioned formula) a-f is an integer of 5-250, and g-j is an integer of 2-249, $5 \leq g+h \leq 250$, and $5 \leq i+j \leq 250$.

[0024]un--- Water Electrolysis Nonaqueous electrolyte of liquid this invention dissolves an electrolyte in a nonaqueous solvent containing a compound containing a specific cyanoethyl group which consists of a nonaqueous solvent and an electrolyte containing a compound containing a specific cyanoethyl group mentioned above, for example, was mentioned above. As an electrolyte used, if used as an electrolyte for nonaqueous electrolyte, all can usually be used.

[0025]As an electrolytic example, LiPF_6 , LiBF_4 , Lithium salt, such as LiClO_4 , LiAsF_6 , Li_2SiF_6 , $\text{LiC}_4\text{F}_9\text{SO}_3$, and $\text{LiC}_8\text{F}_{17}\text{SO}_3$, is mentioned. Lithium salt shown by the following general formula can also be used. LiOSO_2R^3 and $\text{LiN}(\text{SO}_2\text{R}^4)(\text{SO}_2\text{R}^5)$, $\text{Li}(\text{SO}_2\text{R}^6)(\text{SO}_2\text{R}^7)$ and $\text{LiN}(\text{SO}_2\text{R}^8)(\text{SO}_2\text{OR}^9)$ (here $(\text{SO}_2\text{OR}^{10})$) R3-R10 may be mutually the same, or they may differ from each other, and are the perfluoroalkyl groups of the carbon

numbers 1-6.

These lithium salt may be used alone, and may mix and use two or more sorts.

[0026]Especially among these LiPF_6 , LiBF_4 , LiOSO_2R^3 , $\text{LiN}(\text{SO}_2\text{R}^4)(\text{SO}_2\text{R}^5)$, $\text{LiC}(\text{SO}_2\text{R}^6)$ and $\text{LiN}(\text{SO}_2\text{OR}^9)$ are preferred $(\text{SO}_2\text{OR}^{10})$. (SO_2R^7) (SO_2R^8)

[0027]As for such an electrolyte, it is usually desirable to contain 0.1-3 mol/l. in nonaqueous electrolyte by concentration of 0.5-2 mol/l. preferably.

[0028]Although nonaqueous electrolyte in this invention contains a nonaqueous solvent and an electrolyte containing a compound containing the above-mentioned specific cyanoethyl group as an indispensable constituent, it may add other additive agents if needed.

[0029]It is not only suitable as nonaqueous electrolyte for rechargeable lithium-ion batteries, but it can use nonaqueous electrolyte concerning above this inventions as nonaqueous electrolyte for primary batteries.

[0030]2 s following -- It is constituted including a negative electrode, an anode, and the aforementioned nonaqueous electrolyte fundamentally, and, as for a nonaqueous electrolyte secondary battery concerning cell this invention, a separator is usually formed between a negative electrode and an anode.

[0031]As negative electrode active material which constitutes a negative electrode, any of doping and a carbon material which can be dedoped can be used for metal lithium, a lithium alloy, and a lithium ion. Doping and a carbon material which can be dedoped are preferred in a lithium ion also in these. Such a carbon material may be graphite, or may be amorphous carbon, and activated carbon, carbon fiber, carbon black, meso carbon micro beads, etc. are used.

[0032]As negative electrode active material, a carbon material of 0.340 nm or less has a preferred spacing (d002) of a field (002) measured especially by X-ray analysis, and a high crystallinity carbon material which has character with density near black lead or it which is more than 1.70 g/cm^3 is desirable. If such a carbon material is used, an energy density of a cell can be made high.

[0033]As positive active material which constitutes an anode, MoS_2 , TiS_2 , A multiple oxide which consists of lithium and transition metals, such as transition metal oxide [, such as MnO_2 and V_2O_5] or transition metal sulfide, LiCoO_2 , LiMnO_2 , and LiMn_2O_4 and LiNiO_2 , is mentioned. Also in this etc., a multiple oxide which especially consists of lithium and a transition metal is preferred. When a negative electrode is a lithium metal or a lithium alloy, a carbon material can also be used as an anode. A mixture of lithium, a multiple oxide of a transition metal, and a carbon material can also be used as an anode.

[0034]A separator is a porous film and a fine porosity polymer film is usually used suitably. In particular, a porous polyolefin film is preferred and a multilayer film of a porous polyethylene film, a porous polypropylene film or a porous polyethylene film, and polypropylene can specifically be illustrated.

[0035]Such a nonaqueous electrolyte secondary battery can be formed in cylindrical, a coin type, a square shape, and other arbitrary shape. However, basic structure of a cell is not based on shape, but is the same and can perform a design variation according to the purpose. Next, although structure of cylindrical and a coin type cell is explained, what described above negative electrode active material, positive active material, and a separator which constitute each cell is used in common.

[0036]For example, it is stored by battery can where an electric insulating plate is laid in the upper and lower sides of winding and a winding body via a separator which poured in nonaqueous electrolyte for a negative

electrode which applies negative electrode active material to a negative pole collector, and an anode which applies positive active material to a positive pole collector in the case of a cylindrical nonaqueous electrolyte secondary battery.

[0037] A nonaqueous electrolyte secondary battery concerning this invention is applicable also to a coin type nonaqueous electrolyte secondary battery. In a coin type cell, a disc-like negative electrode, a separator, a disc-like anode, and a stainless board are stored by coin type cell can, after this order has laminated.

[0038]

[Example] Hereafter, although this invention is concretely explained through an example and a comparative example, this invention is not limited to these examples.

[0039]

[Example 1] <Preparation of nonaqueous electrolyte> propylene carbonate (PC), and diethyl carbonate (DEC), After mixing at a rate of PC:DEC=55:45 (weight ratio), one weight section of 2-cyanoethyl propionate (1 CE-PPE) expressed with a following formula to this mixed solvent 99 weight section is added, The nonaqueous solvent was prepared so that the quantity of 1 CE-PPE might be 1 % of the weight to the whole (total quantity of PC, DEC, and 1 CE-PPE) nonaqueous solvent. Next, LiPF_6 which is an electrolyte was dissolved in the nonaqueous solvent, and nonaqueous electrolyte was prepared so that electrolytic concentration might become in 1. and 1.0 mol /.

$\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CN}$ [0040] In the carbon powder end of the meso carbon micro beads by <production of negative electrode> Osaka Gas Co., Ltd. (trade name; MCMB6-28, $d_{002}=0.337\text{nm}$, density 2.17 g/cm^3) 90 weight sections, Polyvinylidene fluoride (PVDF) 10 weight section as a binder was mixed, N **MECHIRU pyrrolidone of the solvent was distributed, and the paste state negative electrode mixture slurry was prepared. Next, this negative electrode mixture slurry was applied to the 20-micrometer-thick negative pole collector made from band-like copper foil, it was made to dry and the band-like carbon negative electrode was obtained. The thickness of the negative electrode mixture after desiccation was 25 micrometers. After piercing this band electrode to discoid 15 mm in diameter, compression molding was carried out and it was considered as the negative pole electrode.

[0041] LiCoO_2 (product name: HLC-21, mean particle diameter of 8 micrometers) particle 91 weight section by <Production of anode> Honjo Chemical, Graphite 6 weight section as a conducting material and polyvinylidene fluoride (PVDF) 3 weight section as a binder were mixed, positive electrode mixture was prepared, N **MECHIRU pyrrolidone was distributed, and the positive electrode mixture slurry was obtained. This slurry was applied to the 20-micrometer-thick positive pole collector made from band-like aluminium foil, it was made to dry and the strip positive electrode was obtained with compression molding. The thickness of the positive electrode mixture after desiccation was 40 micrometers. Then, it was considered as the positive electrode by piercing this band electrode to discoid 15 mm in diameter.

[0042] <Production of a cell> thus the obtained disc-like negative electrode and the disc-like anode, and the separator which was able to be further done from a fine porosity polypropylene film 25 micrometers in thickness and 19 mm in diameter were prepared. After laminating each in order of a negative electrode, a separator, and an anode in the battery can of 2032 sizes made from stainless steel, said nonaqueous electrolyte was poured into the separator. Then, in the battery can, the board made from stainless steel (2.4 mm in thickness and 15.4 mm in diameter) was stored, and the battery can (lid) was closed via the gasket of

further the product made from polypropylene. As a result, the airtightness in a cell could be held and the button type nonaqueous electrolyte secondary battery which are 20 mm in diameter and 3.2 mm in height was obtained.

[0043]<Measurement of service capacity>, thus the obtained service capacity of the rechargeable battery were measured by the following method at the room temperature. In this example, the current direction where a lithium ion is doped by the negative electrode was considered as charge, and the current direction dedoped was considered as discharge. Charge was performed by the 4.1V or 1-mA constant current constant-potential-charge method, and when charging current became below 50microA, it was considered as the end. Discharge was performed by 1 mA of constant current, and when voltage amounted to 2.7V, it ended. From the charging capacity of this charging and discharging cycle, and service capacity, charge and discharge efficiency was calculated with the following formula. The result is expressed to Table 1.

Charge-and-discharge-efficiency (%) = {service capacity (mAh/g)} / {charging capacity (mAh/g)} x 100 [0044]

[Example 2] It is made to be the same as that of Example 1 except having used the methyl-2-cyanoethyl carbonate (1 CE-MCE) expressed with a following formula instead of 2-cyanoethyl propionate (1 CE-PPE) in Example 1, Preparation of nonaqueous electrolyte and production of the cell were performed, and the charge and discharge efficiency of the cell was evaluated like Example 1. A result is expressed to Table 1.

$\text{CH}_3\text{OCOOCH}_2\text{CH}_2\text{CN}$ [0045]

[Comparative example 1] In Example 1, like Example 1, preparation of nonaqueous electrolyte and production of the cell were performed, and the charge and discharge efficiency of the cell was evaluated like Example 1 except not having added 2-cyanoethyl propionate (1 CE-PPE). A result is expressed to Table 1.

[0046]

[Table 1]

	シアノエチル基を含む化合物 (略称)	溶媒組成 (重量比)		物 回 充放電効率 (%)	2サイクル目 充放電効率 (%)
		P C + D E C *	シアノエチル基を含む化合物		
実施例 1	1 C E - P P E	9 9	1	6 9 . 5	9 2 . 9
実施例 2	1 C E - M C E	9 9	1	6 8 . 9	9 4 . 3
比較例 1	なし	1 0 0	なし	2 6 . 2	9 6 . 4

* P C : D E C = 5 5 : 4 5 (重量比)

[0047]

[Effect of the Invention] The nonaqueous electrolyte of this invention can inhibit low the reductive cleavage of the solvent which happens when high crystallinity carbon, such as black lead, is used for a negative electrode. As a result, the rechargeable battery using this nonaqueous electrolyte is excellent in the charging and discharging characteristic, the load characteristic, and the battery characteristic in low temperature. Therefore, especially this nonaqueous electrolyte is preferred as nonaqueous electrolyte for rechargeable lithium-ion batteries.

[Translation done.]